AXIS Consortium: Crystal Actuator Applications

AXIS Consortium

- Critical DOD system demonstrations to show merits of single crystals over other smart materials technologies
- Crystal component manufacturing optimization and cost reduction
- Crystal characterization and modeling

TRS Ceramics — Crystal Component and Stack Manufacturing; Bridgman & TGG Development

Georgia Institute of Technology — Device Characterization and Modeling

ACX — Micro-actuators for Commerical Applications

Northrop Grumman — Tonpilz Arrays for Topedo Sonar

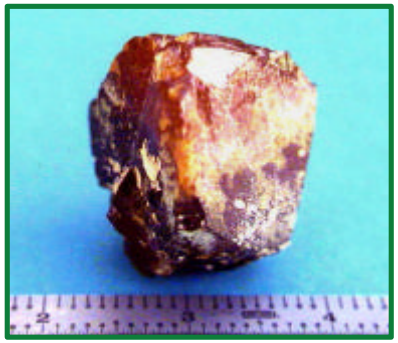
Boeing — Active Flow Control; Stacks for Smart Structures

Government Participants

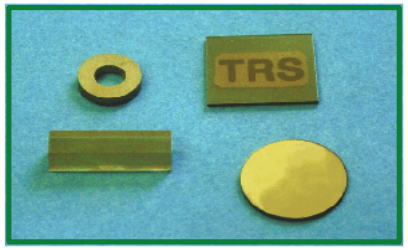
- Crystal/Cymbal Arrays
- Crystal Characterization
- AFC; Patch Actuators

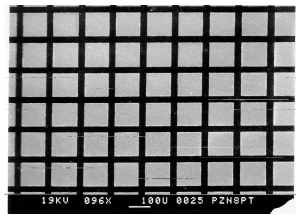
Flux Growth of PZN-PT

- Irregular growth shape & size limitations
- Most developed technique



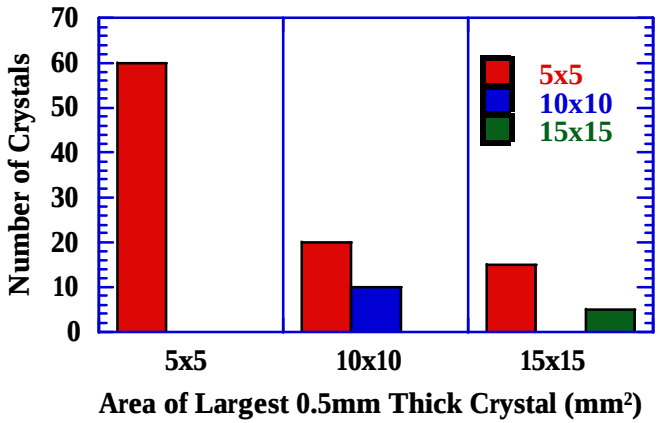
- Largest size: 25 mm x 15 mm
- Rectangular plates as thin as 4 mils, disks, rings, composites



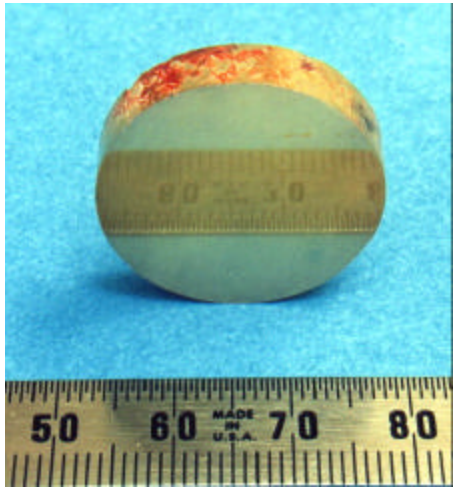


1-3 crystal composite
(posts are 150 mm square)

Each Crucible Yields One of the Following Cases:



Bridgman Growth of PMN-PT



- Faster growth rate
- Simplified orientation and machining
- Reduced cost over flux
- Goal: crystals > 2 inches in diameter

- *Current crystals are 1 inch in diameter*

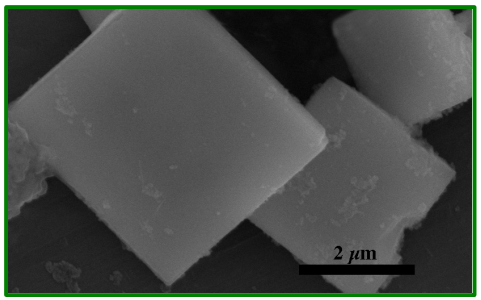
Orientation	k_{33}	s_{33}^E (10^{-12} m^2/N)	d_{33} (pC/N)	*K*	*Fr Cnst* (Hzm)
<100>	0.92	68 to 77.5[+]	1900 to 2100	6100* to 6800	1640

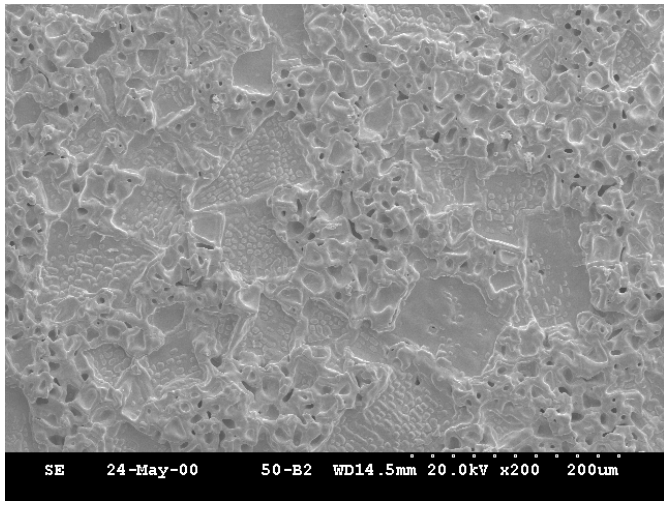
[+]Y_E = 14 to 15 Gpa, 50% stiffer than PZN-PT crystals

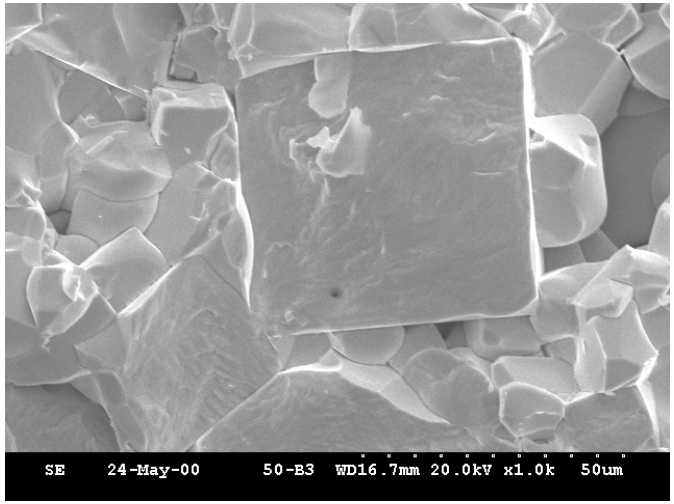
Growth from Hydrothermal $PbTiO_3$

- **Templated Growth of Grain Oriented Ceramics**
- **Chemically *Homogeneous* Microstructure**
- **Large Scale, Low Cost Seed Production**
- **First Demonstration of Growth from PT Seeds**

Hydrothermal PT Platelets





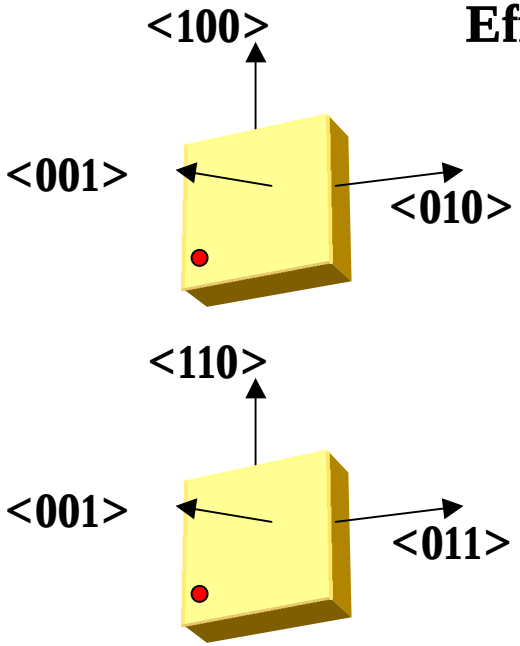


d_{31} Actuation with Single Crystals

Active Flow Control (Boeing, NASA)
Benders (ACX)
Patch Actuators for Active and Passive Damping (NASA, ACX)
Cymbal Arrays (NRL)

All Require d_{31} Mode Actuation

Effect of Orientation on d_{31} (PZN-4.5%PT)



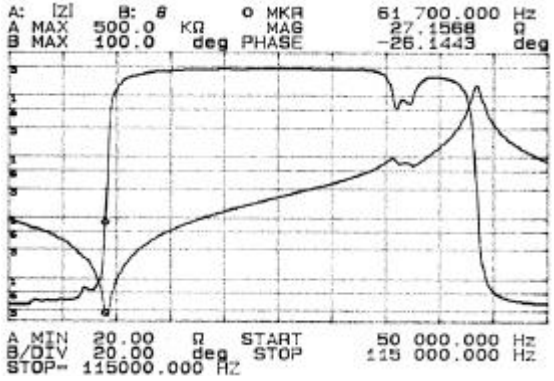
k_{31} ~ 0.5 $\quad$ d_{31} ~ -750 to -850 pC / N

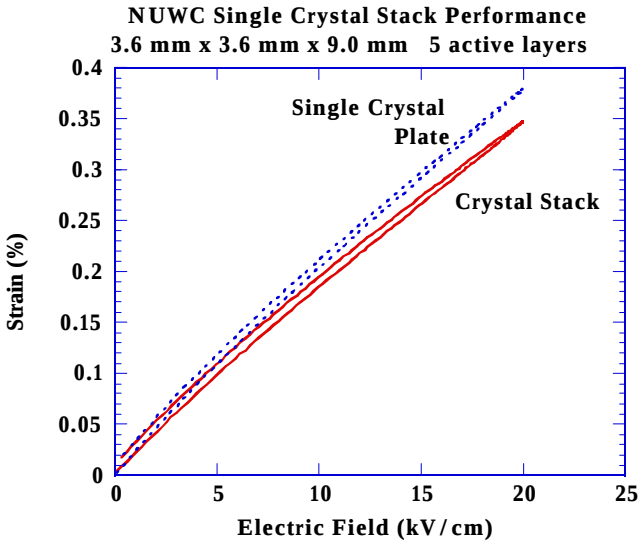
High k_{31}: Improved Passive Damping

k_{31} = 0.8 $\quad$ d_{31} ~ -1000 to -1100 pC / N

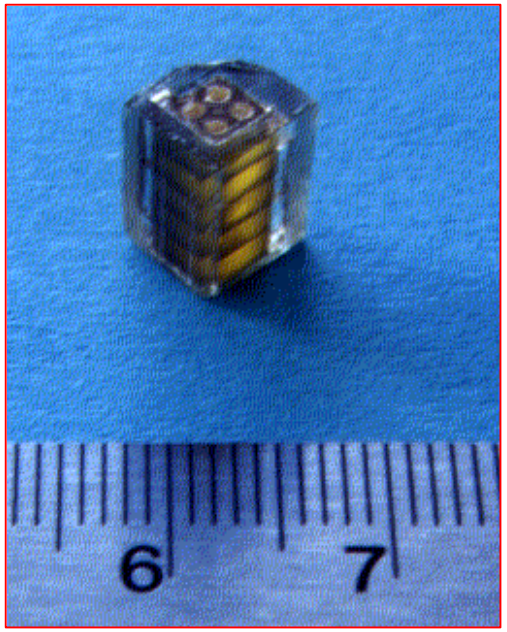
Transducer Stack for NUWC Sonar Application

Resonance: $k_{33} = 0.9$

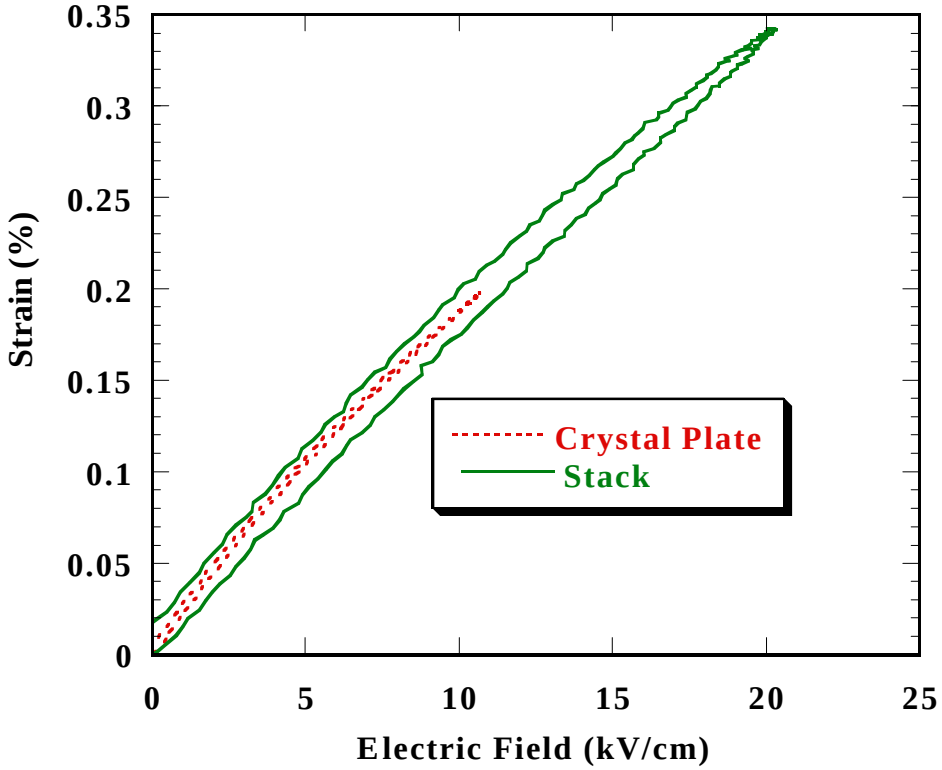


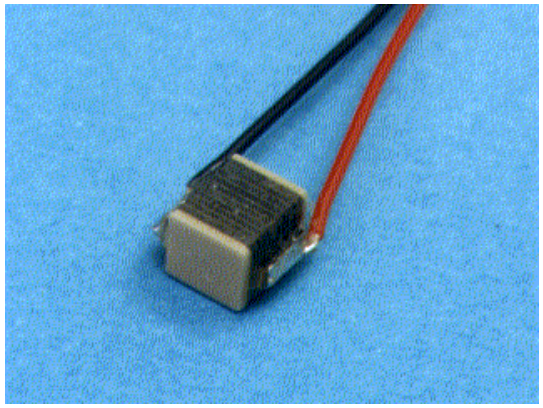


Improved Performance over Actuator Stack Due to Increase in Plate Thickness (1.8mm) & Reduction in Shim Thickness (0.5 mil)

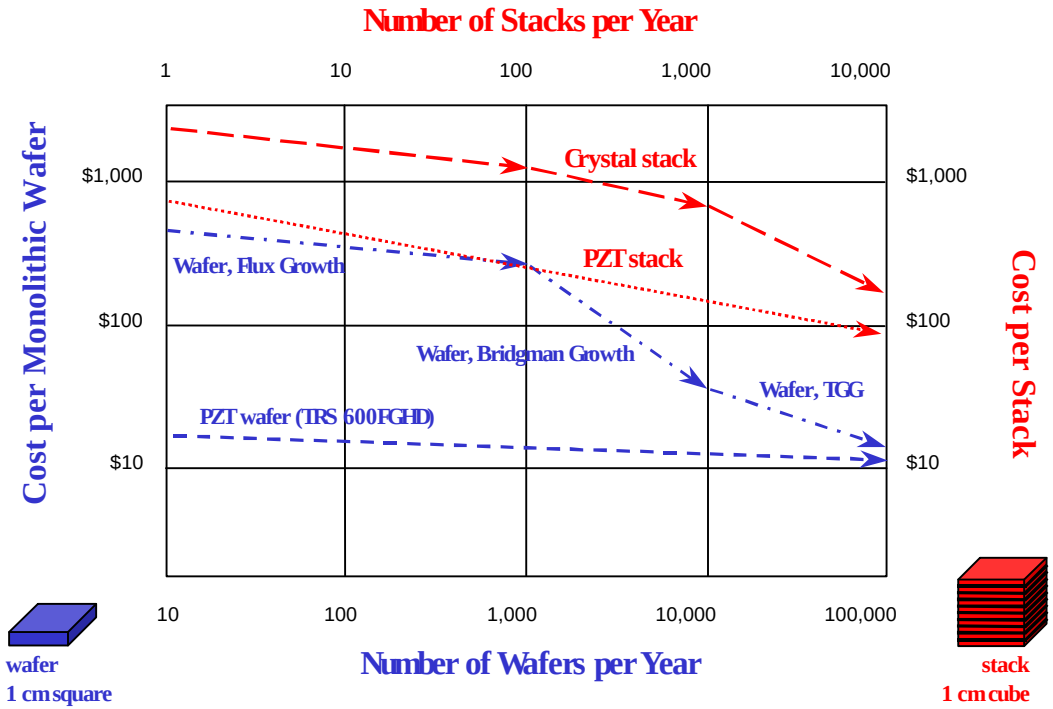


Crystal Actuator Stack





- **Equivalent Strain Response for Bulk Crystal and Stack**
- **Achieved with Reduced Shim Thickness and Increased "Lacyness"**

TRS Goal: Component Cost Reduction

as new manufacturing technologies are developed by TRS